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Site-specific Farming 7

High-clearance sprayer suitable for flag-leaf scanning and immediately post-anthesis N application.
(Courtesy of Brian Arnall, Oklahoma State University. Used with permission.)

Active-optical Ground-based Sensor Algorithms

Tools for Determining Need in Spring Wheat for Immediate-post-anthesis N Application to Enhance Grain Protein

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Sensors can be used to predict possible need in spring wheat for immediately-post-anthesis N application

Hard red spring wheat is a premium, high-protein wheat. The premium over other hard wheat classes is often seen in the higher prices at the Minneapolis grain exchange compared to Chicago or Kansas City. The higher price for Northern Plains hard red spring wheat is the result of its higher protein content. Spring wheat protein is always related to N availability to the crop in proportion to yield supported by the seasonal weather environment. The greater the N availability relative to grain yield, the greater the protein. Conversely, if soil N availability is reduced due to inadequate rate or losses due to leaching, denitrification or ammonia volatilization, grain protein is reduced.

In North Dakota, N fertilization of a spring wheat crop is almost always performed before or at planting. Nitrogen application is sometimes performed in the fall, often in the spring preplant, and a significant acreage is applied at planting or shortly afterwards. After all applications, N loss is possible due to too much water through nitrate leaching or N loss through denitrification or not enough water to move urea into the soil, resulting in ammonia volatilization.

The spring wheat market standard for protein is 14%. In most years, if farmer-delivered grain protein is less than 14%, the price the farmer receives for the grain is reduced due to the discounts for low protein. In some years, there is a premium provided by the buyer for grain with more than 14% protein. There is rarely a premium provided on protein delivered greater than 15%, with only the premium from 14% to 14.9% protein considered.

The decision on whether to supplement the spring wheat crop with a late-season N application is clouded due to the uncertainty of whether a premium and/or dockage will be present when the grain is delivered and whether supplemental N is necessary to achieve market protein. Usually, grain buyer decisions on discounts and premiums are made during the spring wheat harvest period. Previously, there has been no scientific guidance through which growers could estimate whether a post anthesis N application would be helpful.

Once a spring wheat grower predicts that a significant dockage for lower protein or premium for higher protein might be available, the next step is to determine whether supplemental N might be required.

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The landmark work on in-season N application was performed by Finney et al. (1957). This work was done using urea solution, applying a urea rate at various times throughout the growing season to final wheat kernel development. The study showed that early season N application through early jointing resulted in yield increase but low protein increases. The greatest increase in protein was achieved when the urea solution was applied immediately after flowering (anthesis), just when the anthers were withering. As the grain began to develop, the benefit from urea solution application was greatly reduced. They also used the grain harvested to make bread loaves, and they concluded that the protein increases seen in their work was actual grain protein, and not some relic of the fertilizer ammonia itself.

Considerable work has been conducted at NDSU through the experiments of Schatz and Endres at Carrington, McKay at Minot, and others.

Table 1. Protein and yield with foliar N rates applied post-anthesis as UAN, Carrington 1990-91 dryland.

	Pounds N per acre				
	0	15	30	45	60
Year	Protein, percent				
1990	12.0	12.3	12.5	12.6	13.2
1991	12.9	13.6	15.9	16.4	16.9
Ave Protein	12.4	12.9	14.2	14.5	15.0
Ave Yield	50.3	50.6	49.7	46.7	43.4

These studies indicate that the 30 pounds N-per-acre rate applied immediately post-anthesis is the most profitable N rate and timing to achieve greater spring wheat grain protein. In subsequent studies exploring N sources with "greater efficiency" compared to UAN, the higher-efficiency fertilizers applied as a foliar were no more effective than UAN and also needed to be applied at the 30 pounds N-per-acre rate to increase grain protein similar to 30 pounds N per acre as UAN. The 1 to 3 gallon-per-acre recommendations associated with these products had insignificant grain protein effects. The rate of N was too low to be effective. A full PDF report is available for download by visiting *www.ndsu.edu/agriculture/sites/default/files/2022-06/foliarNreport.pdf*.

Use of sensors to predict possible need for immediately post-anthesis N application

Active-optical light sensors have been available for agricultural use for nearly 30 years. People are most familiar with passive light sensors. A passive light sensor is a sensor that can detect visible light and other electro-magnetic radiation emitted by the sun that is reflected and sensed by the instrument. Examples of passive light sensors are aerial photography and satellite imagery. An active-optical sensor emits its own light in specific wavelengths and has the ability to measure the intensity of the light reflected into the instrument compared to the light the instrument emitted. The active-optical sensors that relate to this publication have the ability to filter out ambient light through their modulated light pulses. The modulated light pulses are similar to light-based UPC codes found on food packaging, based on the length of their on-off patterns. The sensors read only the light received in the same modulated pattern. The readings the instrument records are not influenced by changes in sunlight, cloud cover or clouds passing over during sensing and therefore provide similar readings whether they are used at night or during the day. The only conditions that disrupt measurement consistency is leaf wetness from rain, recent irrigation or early morning dew.

The two active-optical sensors recently tested in spring wheat N-rate trials are the GreenSeeker™ (Trimble, Sunnyvale, CA) and the Holland Scientific Crop Circle™ (Holland Scientific, Lincoln, NE). The algorithms developed using these instruments utilized N-rate research performed in North Dakota during the past decade. The GreenSeeker and Holland Scientific Crop Circle sensors generate red-NDVI; however, the red-NDVI relationship with grain protein when scanned at flag-leaf was inconsistent. The red edge NDVI, which only the Crop Circle had, provided much better relationships to grain protein. The GreenSeeker is based on a red sensor with 660nm wavelength and near infrared with 770nm wavelength. The Crop Circle red sensor is based on red 670nm wavelength and near infrared with 760nm wavelength. The Crop Circle red edge sensor uses the same near infrared 760 nm wavelength, and the red edge band is 730nm wavelength.

Sensor use

To use an active-optical sensor for the purpose of grain protein enhancement, the wheat should be scanned during the flag-leaf stage (starting when the flag collar is visible; Zadoks 39/Feekes 9). The flag-leaf stage scan values are related to spring wheat protein. For practical reasons, a flag-leaf scan may be made during flag-leaf fungicide application to save a trip across the field. Spring wheat in North Dakota is typically treated with a fungicide at early anthesis (Zadoks 61 or Feekes 10.5.1).

Fungicide application and N fertilizer application should not be made at the same time. If fungicide and N fertilizer are applied at the same time, fungicide activity might be reduced, the flag leaf might be damaged leading to lower yields, and the effect of the N fertilizer on grain protein would be reduced, even if a urea solution were used to minimize leaf damage instead of UAN.

Additional factors to consider

A scan of the field at about V5 growth stage (five true leaves present; Zadoks 15) should be conducted to help determine the need for protein enhancement. If the scanner value is less at flag leaf than at V5, there will be no profitable gain from supplemental N application. The lower value at flag leaf is almost always the result of drought and reduced canopy and greenness from the drought.

If the scanned red edge NDVI is greater at flag leaf than at V5, then the red edge NDVI value can be used to predict whether or not an immediate post-anthesis N application would result in greater protein.

There are two values to consider depending on the general protein content trait of the cultivar used.

If the cultivar tends to yield grain with high protein regardless of conditions, then the high protein value should be used. If the cultivar tends to be a low to medium protein type, then the low to medium value of red edge NDVI should be used. The decision is a yes/no one. If the reading is greater than the table value, then the probability of any profitable gain from supplemental N is low. If the reading is less than the table value, the probability of a profitable gain from supplemental N is high if premiums for higher protein and/or dockage for low protein are great enough. There are and will

Spring wheat at immediately post-anthesis stage of growth, ready for supplemental N application if warranted. (NDSU image)

be differences in wheat tint between varieties. The recommendations in the table below are based on experiments over several cultivars. Use of an N-sufficient area within the field and comparing the red edge NDVI of the strip with values in the rest of the field will provide confidence to growers that their decision to fertilize or not is justified.

Red edge NDVI values at flag-leaf to determine likelihood of protein increase with immediate-past-anthesis N application. Red edge NDVI values less than those in the table would support agronomic consideration for post-anthesis N application.

Cultivar type	Red edge NDVI
High protein*	0.3
Low to medium protein	0.4

* An example of a high protein cultivar would be Glenn.

References

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